

Instruction Sheet I

Identifying Factors Related to the Venting and Ventilation Process

PURPOSE OF THE VENTING AND VENTILATION PROCESS

Venting is the removal of combustion products to the outdoors through a system of piping, ducts, flues, vents, chimneys or stacks especially designed for that purpose.{1} A properly designed and installed venting and ventilation system will serve the following purposes:

- (1) Convey all hot combustible gases to the outside atmosphere
- (2) Prevent overheating of nearby walls or framing
- (3) Prevent condensation of moisture from the water vapor present in the combustible gases
- (4) Provide for air circulation and adequate oxygen supply for the appliance and for the occupants of the dwelling

Normally, combustion products of propane in air mixtures are not harmful when the appliance is achieving complete combustion. However, when combustion is incomplete the products can be harmful to both life and property.

COMBUSTION OF PROPANE

The combustion of propane is a chemical reaction. It is a method of changing a fuel source into a useful form of energy, such as heat.

- (1) **Requirements for Combustion.** The basic elements of common fuel gases are hydrogen (H) and Carbon (C).{2} The model shown in Figure 1 represents propane C₃H₈.

The oxygen needed for combustion is present in the air. The ignition source must provide enough heat to the mixture of fuel and oxygen to raise the temperature of the propane to its ignition temperature. The ignition temperature of propane is between 920-1120° F.{3}

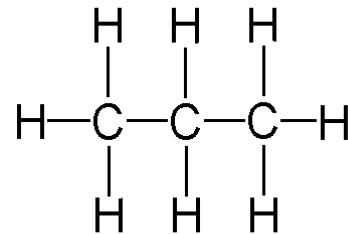


Figure 1. Propane Model

As illustrated in Figure 2 when combustion takes place and the hydrogen burns, water vapor is produced. The water molecule (water vapor) represented by the symbol H_2O consists of two hydrogen atoms and one oxygen atom. The complete burning of carbon in fuel gas forms carbon dioxide. The symbol for carbon dioxide is CO_2 . It has one atom of carbon and two atoms of oxygen in each molecule.

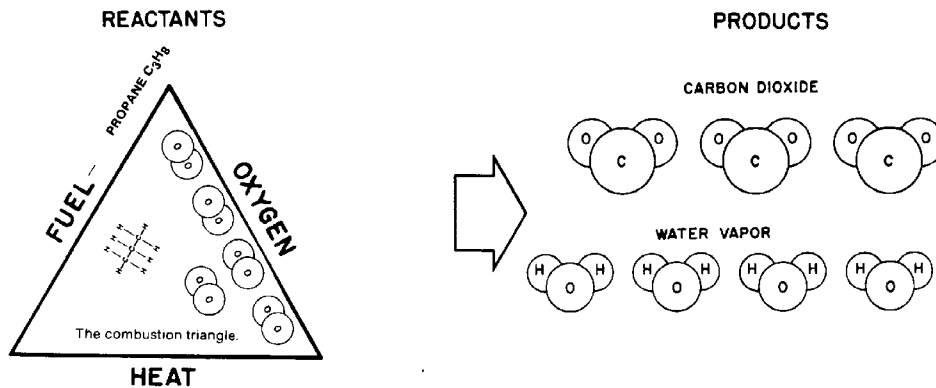


Figure 2. Combustion of Propane and Oxygen

- (2) **Combustion Products.** When propane and air are burned in the correct ratio (1 cubic foot of propane to approximately 25 cubic feet of air), complete combustion takes place.{4} Since propane is a mixture of hydrogen and carbon, certain products are generated when burned in the presence of oxygen. These products are water vapor (H_2O) and carbon dioxide (CO_2). The carbon in the propane joins with the oxygen in the air to produce carbon dioxide (CO_2). Water vapor is formed when the oxygen in the air joins with the hydrogen in the propane. For example, when 1,000,000 Btu's of heat is generated with propane, ten (10) gallons of water are produced. The nitrogen present in the air remains unchanged after combustion.

The carbon dioxide and water vapor formed in burning plus the nitrogen in the reactants which enter with the combustion air together are called combustion products. These products are commonly known as flue gases.{5}

- (3) **Incomplete Combustion.** When combustion is incomplete harmful products can be generated. Thus far only complete combustion of propane has been considered. To obtain complete combustion enough air must be supplied to the combustion process. This air must have a reasonably normal oxygen (20%) content. (1) It must be mixed well with the propane and/or flame. Complete burning of propane produces harmless carbon dioxide and water vapor. If not enough air is supplied other products will be generated which include (a) carbon monoxide, (b) excessive water vapor, (c) aldehydes and (d) soot. Some of these products are harmful, especially carbon monoxide which is represented by the symbol (CO).{6}

(a) **Carbon Monoxide.** Carbon monoxide gas has no odor, color, or taste so it cannot be detected by bodily senses. Carbon monoxide is

flammable. Carbon monoxide can enter the body only through the respiratory system. Inhaled carbon monoxide is absorbed into the blood. It combines with the hemoglobin of the blood to exclude the oxygen. CO combines with hemoglobin in the blood to a much greater extent than oxygen and remains in the blood longer than oxygen. Therefore, it acts to reduce the oxygen-carrying function of the blood. A person exposed to carbon monoxide can die from a lack of oxygen.

The amount of carbon monoxide which the blood absorbs depends chiefly on two things: how much carbon monoxide is in the air, and the length of exposure. Adverse effects of carbon monoxide on humans are reduced by periods of breathing fresh air. The degree of recovery depends on the number and length of those periods. Over 200 parts of oxygen are needed to replace one part of carbon monoxide in the blood. The exposed person's general state of health and degree of physical activity are other factors involved in the effects of carbon monoxide on the body. (2)

- (b) **Excessive Water Vapor.** Excessive water vapor can also be produced. If sulfur impurities exist in the propane, sulfur deposits may also be produced. As a result, the condensed water will combine with the sulphur deposits to form sulfuric acid.
- (c) **Aldehydes.** Aldehydes, another class of compounds, also may be formed in incomplete combustion. While carbon monoxide is odorless, aldehydes have a sharp, penetrating odor. They are readily detected by smell, even at very low concentrations. The odor of aldehydes differs from odorants added to propane and the two should not be confused. The absence of aldehydes does not assure that carbon monoxide is not present in flue products. However, if the odor of aldehydes is present then carbon monoxide almost always will be present. Aldehydes themselves also are toxic. (3)
- (d) **Soot.** Carbon soot, can also be generated by improper combustion.

OPERATION OF GAS VENTING SYSTEMS

Poor venting of an appliance restricts the flow of air into an appliance. Lack of ventilation around an appliance may lower the oxygen content in the air. Spillage of combustion products into the room reduces the oxygen supply in the air. Since any of these conditions can cause incomplete combustion, adequate ventilation must be provided.

A chimney or vent system operates because there is a natural draft in the system. Draft is the force that draws the combustion products up the chimney or vent. This

draft is created by the fact that hot air in the vent is lighter than the cool air which surrounds it.

(1) **Vent Gases.** Vent gases, as illustrated in Figure 3, include the (a) products of combustion, (b) excess air, and (c) dilution air.

(a) **Products of Combustion.** The products of combustion result from the combustion of propane with oxygen in the air, including the inert gas, but excluding excess air. The air required for complete combustion is referred to as combustion air. Combustion air includes both primary air and secondary air.

Air which is mixed with propane before the propane leaves a burner port to burn is called primary air. In most burners only part of the air ideally needed for burning the propane is supplied as primary air. The rest of the air needed for complete burning of propane is supplied as secondary air from around the flame.

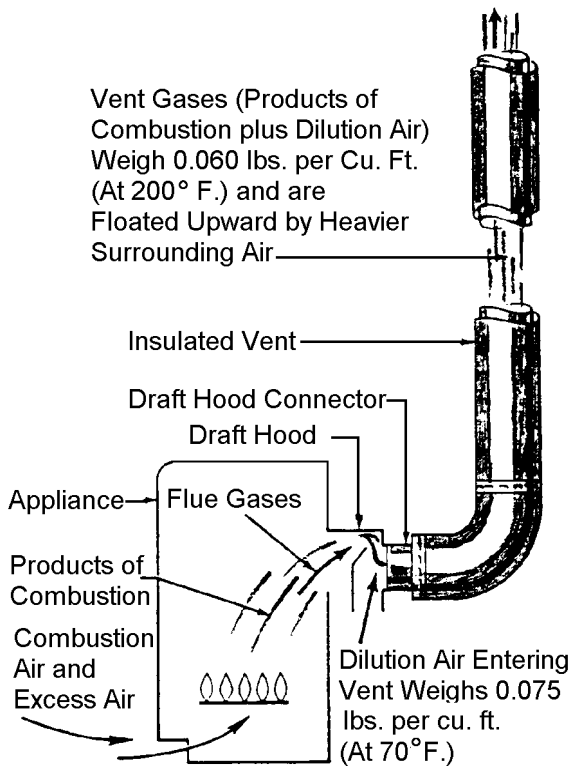


Figure 3. Operation of a Gas Vent

(b) **Excess Air.** Excess air is air which passes through the combustion chamber without burning. In other words, the air in excess of the ideal amount needed for complete combustion is called excess air. (4)

(c) **Dilution Air.** Dilution air is air which enters a draft hood and mixes with the flue gases.

Approximately 240 pounds of vent gases must be removed for each 100,000 Btu's of gas burned in an appliance.

(2) **Motive Force in Vents.** The motive force of a venting system can be explained by referring to the U-shaped cylinder illustrated in Figure 4 which operates the same as a typical appliance venting system. The hotter, lighter

combustion products will rise out the top of the cylinder on the left. The cooler heavier room air will move into the cylinder on the right and appear to push the combustion products upward. The heat source will heat the room air which, when hot, will raise the combustion products and make the movement continuous.

The difference in weight of the columns of air causes the draft which makes the venting system work. The draft force is very small, amounting to only a fraction of an inch of water column pressure.

It is essential, therefore, that venting systems be constructed so the motive force is not wasted overcoming resistance to flow. The vent should be as straight as possible and sharp turns or restrictions should be avoided.{7}

If the gases are cooled enough, the upward motion stops and combustion gases spill through the appliance draft hood into the atmosphere around the appliance. Therefore, in order for the vent to work properly the flue gases in the vents should be kept as hot as possible to insure a strong, positive draft. From these facts it can be seen that a gas vent must possess high insulating value so it is able to confine the heat of the combustion gases inside the vent. The heat provides the "power" to exhaust all combustion gases to the outdoors without danger of spillage or draft failure.{8}

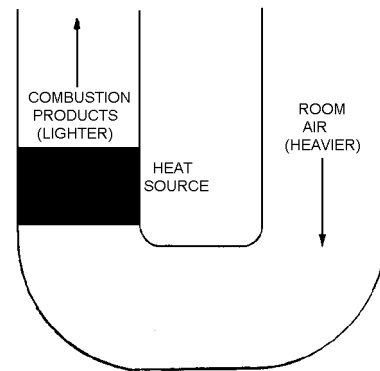


Figure 4. Theoretical Chimney or Vent Draft Action

The combustion reaction process produces hot gaseous products which are lighter than the cooler surrounding air. Therefore, the hot gases tend to rise. The vent pipe system conveys the rising gases to the outside. As the hot gases leave the inside of the house, the atmospheric pressure in the house is slightly lowered.{9} The lower pressure in the house causes air from the outside to infiltrate to ventilate the house. If the house is sealed so tightly that ventilation air cannot infiltrate, venting will stop and the combustion process would stop. Venting, (the process of removing the products of combustion) and ventilation, (the process of supplying fresh air) must always be considered together. They are both part of the same system and must balance each other.

- (3) **Water Maintained in Vapor Form.** As discussed previously, the combustion products resulting from burning propane contains water vapor. Approximately one gallon of water is formed when burning 100,000 Btu's of gas.{10} This

amount of water will be made in only 1 hour by a 100,000 Btu per hour size furnace. If water vapor was allowed to condense inside the house over a period of time, it would cause considerable damage to walls, furniture, and other household contents.

The heat of combustion will maintain the water in the form of vapor and cause all the flue products to pass up the vent to the outside atmosphere. Water vapor at high temperatures is a gas. It only becomes visible as a liquid after it has been cooled below its dew point.{11} Thus, a vent passes the water vapor to the outside atmosphere where condensation, if it occurs, is not harmful.

FACTORS AFFECTING THE DESIGN AND OPERATION OF VENTING SYSTEMS

- (1) **Venting Gas Temperature.** Since the temperature inside the vent represents the power available to operate the vent, the Btu capacity of the vent is dependent on the temperature. The hotter the vent gases the lighter they are and the greater is the force which expels them through the vent. (5)
- (2) **Heat Loss.** As the hot flue gases travel through the vent system they lose heat to the walls of the vent. As the gases cool they become more dense and the draft effect is lessened.{12} Single-wall metal vents conduct heat readily to the surrounding air. Some non-metallic materials used for vents may absorb large amounts of heat. Double-wall metal vents are often preferred because of the insulating quality of the air space between the walls and because the relatively small mass of metal in the inner wall does not absorb much heat. (6)
- (3) **Vent Height.** As can be seen from Figure 4, page 9, the taller the columns of hot gases the more will be the driving force tending to displace them. In general, increasing the vent height increases the draft. Because increased pipe length also increases the resistance to flow, there will be a limit at which no further benefit will be gained by increasing the vent height. This limit is not usually encountered in actual practice. (7)
- (4) **Vent System Capacity.** The volume of flue gases produced by a gas appliance is approximately proportional to the Btu input. Every vent system has a maximum input beyond which no more flow can be accommodated. When this limit is exceeded a portion of the combustion products will not enter the vent but will spill at the draft hood. Each vent also has a minimum input below which the gases cool and water condenses before the gases reach the outside. The range between the maximum and minimum inputs is called the vent capacity and the vent will operate properly only between these inputs. The capacities of vents can be determined by mathematical calculation or consultation of tables prepared for that purpose. (8)
- (5) **Restriction to Flow.** Small sized venting restrictions or changes in direction of the vent all cause resistance to flow and impede good venting. (9)

- (6) **Ambient Temperature.** As can be seen from Figure 4, page 9, the cooler the air in the right cylinder the heavier it will be and the greater the motive force will be to move gases through the vent system. If the air in the right cylinder is room air, this effect usually stays fairly constant. However, if the combustion air is taken directly from the outside, as in some installations, the vent functions better on cold days. (10)
- (7) **Condensation.** The potential to produce condensate must be controlled to limit corrosion. The period when the vent is wet is called the "wet time". Whenever the vent is wet with condensate, a potential for corrosion exists. The corrosion may be accelerated by contamination of the combustion air by household chemicals. If this occurs, the condensate may become highly acidic. There are two practical ways to limit the potential for corrosion:
- (a) provide clean, outdoor air to the appliance
 - (b) limit the length of wet time in the vent

References:

- (1) NIOSH Criteria for a Recommended Standard "Working in Confined Spaces," p. 25 & 26.
- (2) Fundamentals of Gas Combustion, American Gas Association, p. 16.
- (3) Ibid., p. 18.
- (4) Ibid., p. 21.
- (5) Fundamentals of Gas Appliance Venting and Ventilation, American Gas Association, p. 5.
- (6) Ibid., p. 6.
- (7) Ibid., p. 6.
- (8) Ibid., p. 6.
- (9) Ibid., p. 6.
- (10) Ibid., p. 6.